UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

ELECTRICAL STERILIZING EQUIPMENT FOR FARM DAIRIES

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BULLETIN 650

JUNE, 1941

UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

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ELECTRICAL STERILIZING EQUIPMENT FOR FARM DAIRIES[1,2]

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INTRODUCTION

THE CALIFORNIA DAIRY law requires that on dairy farms all equipment coming in contact with milk be thoroughly washed and sterilized, each time used, by exposing it for at least 15 minutes to water or water vapor having a temperature above 170° Fahrenheit. To meet this requirement, steam is commonly used for the sterilizing, and often also for heating wash water. Various types of steam-generating equipment are available, including those using electricity as a source of heat. Electric sterilizers, developed about 1924, are now popular because of simplicity, low fire hazard, automatic operation, ease of installation, cleanliness, freedom from odors, and the small amount of attention they require.

In response to many inquiries concerning the characteristics and operating costs of electric sterilizers, this type of equipment was investigated; the results are given in this bulletin. The investigation was divided into four parts: (1) a study and laboratory tests of various types of electrical steam generators, (2) laboratory tests to determine the steam required to heat sterilizing cabinets and water, (3) a field survey of dairies to determine the sterilizing practices and the amount of steam used, and (4) observations on dairies to determine the operating costs.

SELF-CONTAINED STERILIZER

Two types of electric sterilizer equipment are used on California dairies: the "self-contained," in which the steam generator and the sterilizing cabinet are one unit; and the "boiler," in which the steam generator and the sterilizing cabinet are separate units.

The "self-contained" sterilizer (fig. 1) is a sheet-metal box with either a removable or a hinged lid and with a trough on the bottom in which the heating element is located. It is also equipped with legs, a rack on the bottom to keep the equipment above the water, and an outlet for withdrawing water. The placing of water in the box and the turning on and

[1] Received for publication October 29, 1940.

[2] This publication is the fifteenth of a series reporting results of investigations conducted by the California Agricultural Experiment Station in coöperation with the California Committee on the Relation of Electricity to Agriculture.

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[4] Field Engineer for California Committee on the Relation of Electricity to Agriculture; resigned January 1, 1941.

off of the electricity must be done manually, although one can obtain a heating element that will automatically cut off when it is not covered with water.

Such sterilizers have been commercially available for about fifteen years; and some are still in use after twelve years' continuous service. They have the advantages of low initial and operating costs, of the steam generator and sterilizing cabinet being one unit, and of the heating element being exposed and easy to clean; but they have the disadvantage of providing no controlled steam for sterilizing surface coolers in place

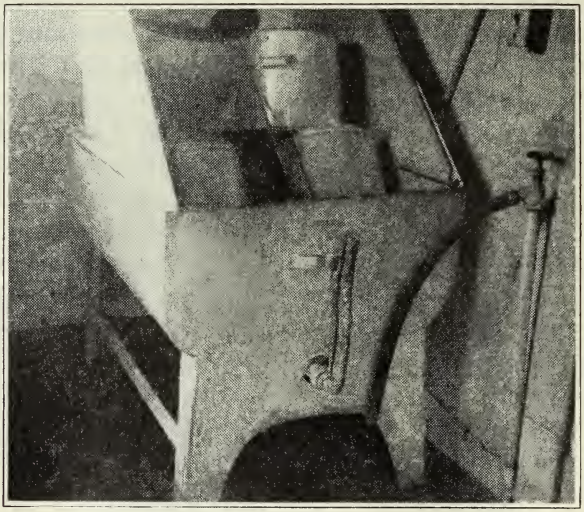

Fig. 1.—A self-contained type of sterilizer filled with equipment ready for sterilizing.

or for heating water in a sink. They are made in several sizes (each with a 5-kilowatt heating element), ranging from 10 to 20 cubic feet in capacity, but rated on a basis of the number of 10-gallon cans they will hold, such as a no. 2, a no. 4, and a no. 6. The initial costs range from about $50 to $65 for units with the plain immersion heaters and from about $65 to $80 for units with the semiautomatic heating elements that offer protection against the element's burning out when not immersed.

Figure 2 shows the results of a test on a self-contained sterilizer of the no. 4 (four 10-gallon cans) size. The initial temperature of the water was 63° F. About 19 minutes was required for heating it to 170°; and about 27 minutes for heating it to 208°, at which point the current was cut off. About 17 minutes was necessary to cool from 208° to 170°, making a total of 25 minutes above 170°. The energy consumption was 2.3 kilowatt hours.

BOILER-TYPE STERILIZERS

The "boiler" type of sterilizers (figs. 3 and 4) consist of two separate units: the boiler that generates the steam and the cabinet in which the equipment is sterilized. This type of sterilizer has the advantages of controlled steam under pressure that can be used as desired, adaptability to heating water either in the boiler or by steam, and adaptability to automatic controls. It is, however, relatively higher in initial and operat-

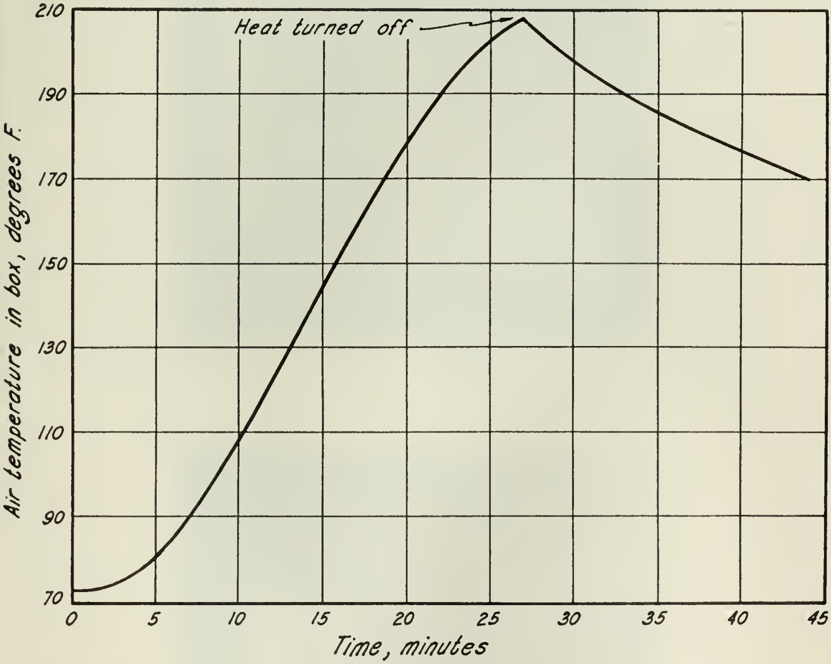

Fig. 2.—Results of test on a four-can self-contained sterilizer, under the following operating conditions: 3 gallons of water in the sterilizer; 76° F air temperature; 63° initial water temperature; 5-kilowatt heating element; and 2.3 kilowatt-hours of energy used.

ing costs, has more parts to get out of order, is more difficult to install, and requires more floor space. The sterilizing cabinet and the steam generator, being individual units, are normally sold separately. There are several kinds of electric steam boilers used for supplying the steam; these can be divided into two general types: the "accumulator" and the "instantaneous."

Accumulator Boilers.—Accumulator boilers (figs. 3 and 4) depend on the accumulation of sufficient heat in the tank to generate all the steam for the sterilizing. Ordinarily they consist of a relatively large

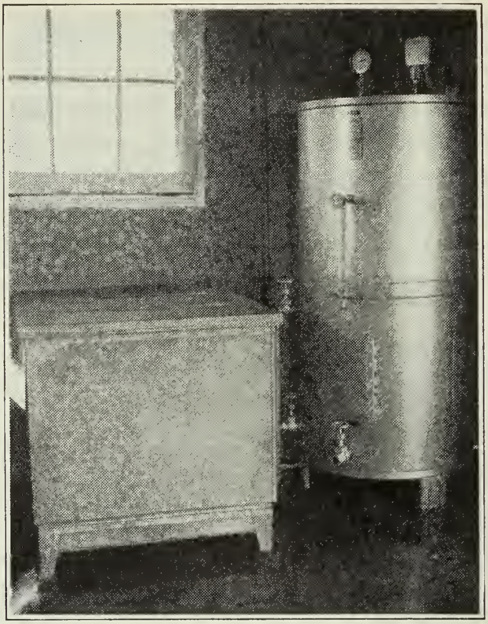

Fig. 3.—A 30-gallon accumulator boiler connected to a horizontal sterilizing cabinet.

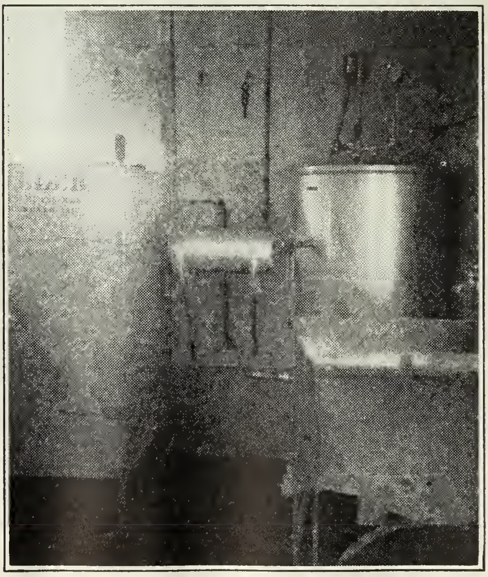

Fig. 4.—A vertical sterilizing cabinet connected to an accumulator boiler. The small round drum in the center is a water softener connected in the feed line to the boiler.

metal tank, heavily insulated and covered on the outside with a sheet-metal casing (fig. 5). They are equipped with a safety valve, a pressure gauge, an automatic pressure-regulating switch, a water gauge, a heating element, and pipelines for the cold-water inlet, steam outlet, and for blow-off. They are normally designed to operate at a maximum pressure of 100 pounds per square inch. Two sizes are now available—one with

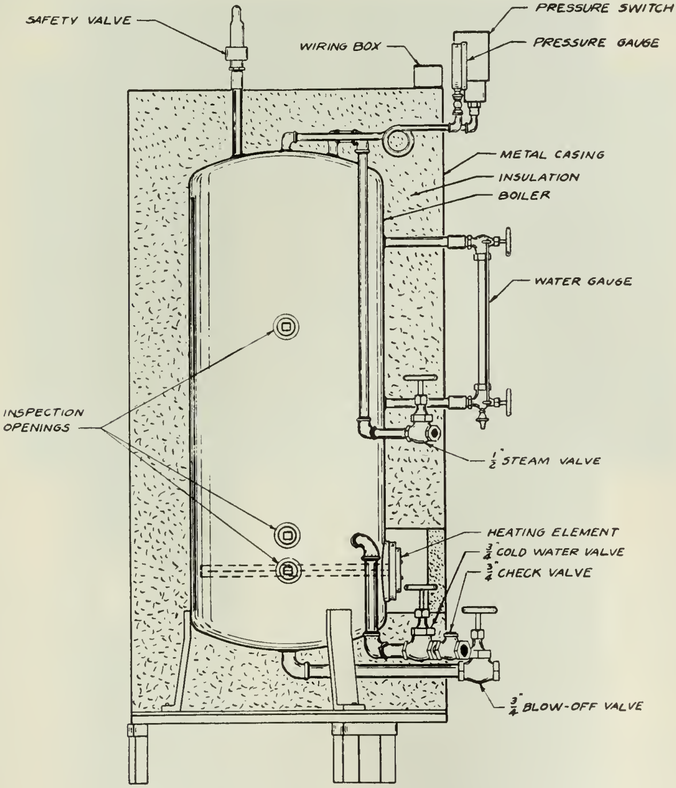

Fig. 5.—Cut-away view of an accumulator boiler.

about a 75-gallon tank that will store between 60 and 70 pounds of steam at 100 pounds per square inch pressure, and one with about a 30-gallon tank that will store 25 to 30 pounds of steam at 100 pounds' pressure.[5] The common sizes of heating element on the large boilers are 3,000 watts and on the small 1,500 watts; however, they may be equipped

[5] Pounds of steam and pounds pressure should not be confused. The former is the weight of steam or an equivalent weight of water converted into steam. For example, one gallon of water, which weighs 8.33 pounds, can be converted into 8.33 pounds of steam. Pounds pressure is the pressure per square inch on the boiler shell as would be shown on a pressure gauge. It is not the weight of steam that can be obtained from the boiler.

with any standard-sized element up to 5,000 watts. The initial costs range from $175 to $300, the cost varying with the size and the manufacturer.

The accumulator boilers have the advantages of high load factor, complete automatic electric operation, a large volume of steam stored under

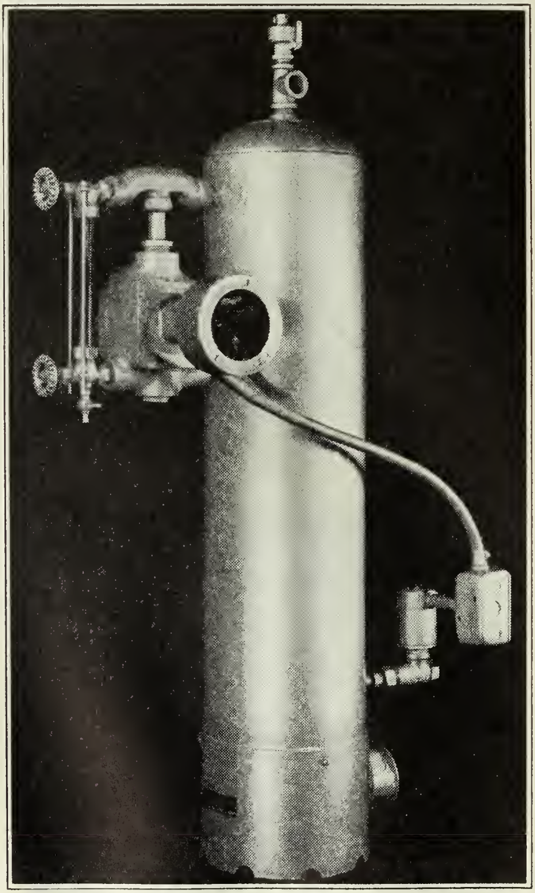

Fig. 6.—A "no pressure" instantaneous boiler equipped with an automatic water valve.

pressure, steam always available, little trouble where hard water is used, easy installation, low attendance requirements, and the low wattage usually not requiring any special wiring and sometimes contributing to better electric rates. Their disadvantages are their size, the initial cost, high operating pressures making them more subject to leaks, and continuous operating making leaks especially objectionable.

Instantaneous Boilers.—Instantaneous boilers, though able to store some heat energy, depend mainly on their instantaneous steam-generating capacity to supply the heat for sterilizing. They operate only when steam is needed—usually less than two hours' total time per day. There are several makes of this type, each with individual features; in general, however, their advantages are capacity to supply a reasonable amount of steam for a long period, reduced operating cost when sterilizing is done only once a day, less leakage because of low pressures, and reduced

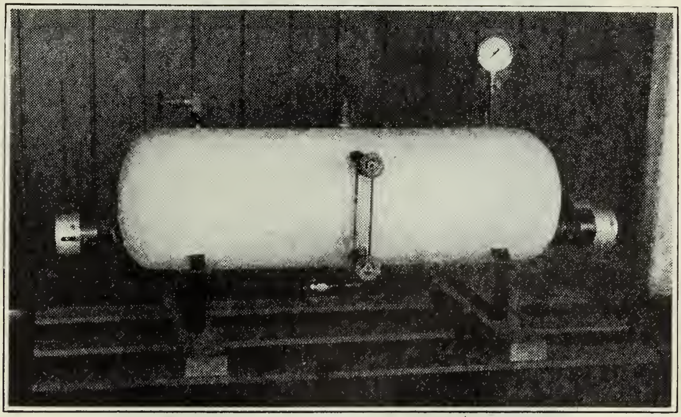

Fig. 7.—A low-pressure instantaneous boiler; with a tank capacity of 18 gallons.

importance of leaks because of the short period of operation. Their disadvantages are poor load factor, a large connected load (which sometimes results in special wiring and higher electric rates), trouble with heating elements where hard water is used, and greater attendance required.

Figure 6 shows an instantaneous boiler known as a "no-pressure" type because it is designed to furnish steam at less than 5 pounds' pressure. It consists of an uninsulated 7-gallon tank equipped with heating elements inserted in the bottom, safety valve, gauge glass, automatic magnetic valve to maintain the water level above the heating elements, and outlets for both steam and hot water. This boiler may be obtained with 5-, 10-, or 15-kilowatt heating elements and costs about $125. It is compact and relatively low priced, but has no steam storage and no protection against water failure.

Figure 7 shows an instantaneous boiler of the low-pressure type consisting of an 18-gallon insulated tank equipped with three 5-kilowatt heating elements. Accessories include a safety valve, a gauge glass, a pressure gauge, outlets for steam and water drainage, and automatic

low-water cut-offs on the heating elements. This boiler also may be obtained with one or two 5-kilowatt heating elements, and the cost ranges from $125 to $200. It has some steam storage (usually up to 15 pounds' pressure), is medium-priced, and is protected against water failure; it has, however, manual control for both water and electricity except for the protection against low water, and is relatively difficult to install.

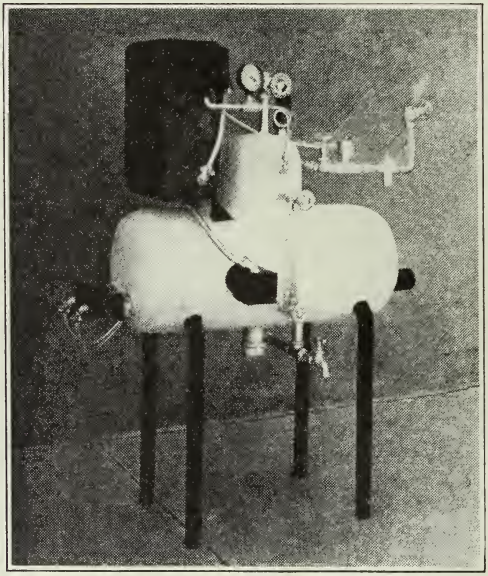

Fig. 8.—A low-pressure instantaneous boiler equipped with automatic controls for both water and electricity.

Figure 8 shows an instantaneous boiler of the low-pressure type which is automatic except for initial starting and final stopping. It consists of a 13-gallon insulated tank equipped with a safety valve, a gauge glass, a pressurestat to maintain automatically a set pressure, an automatic water regulator, a main magnetic switch, three 5-kilowatt heating elements, outlets for steam and hot water, and a cleaning port. This boiler, though relatively expensive (about $300), has the advantages of automatic operation, low attendance requirements, steam storage, and easy installation.

Sterilizing Cabinets.—The sterilizing cabinets, not being sold with the steam generator, are usually built to order by a local sheet-metal shop or constructed by the dairyman.

Since the greatest use for steam on most dairies is to heat the sterilizing cabinet, this piece of equipment should be properly designed and

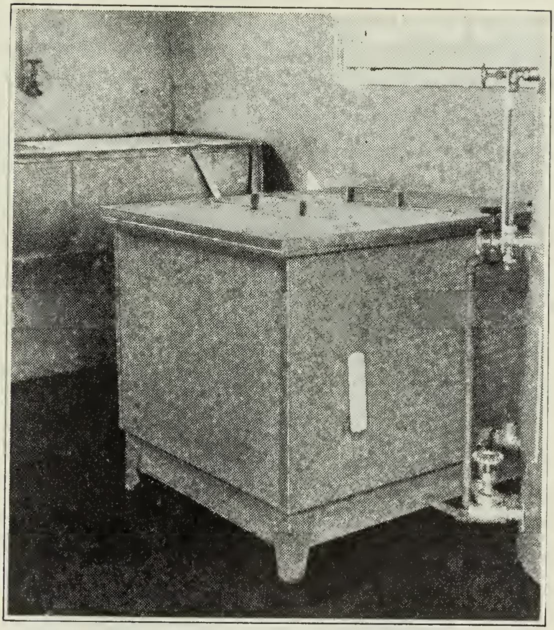

Fig. 9.—A well-made horizontal sterilizing cabinet connected to an accumulator boiler on the right. This chamber has sealed walls insulated with ½ inch of fiberboard.

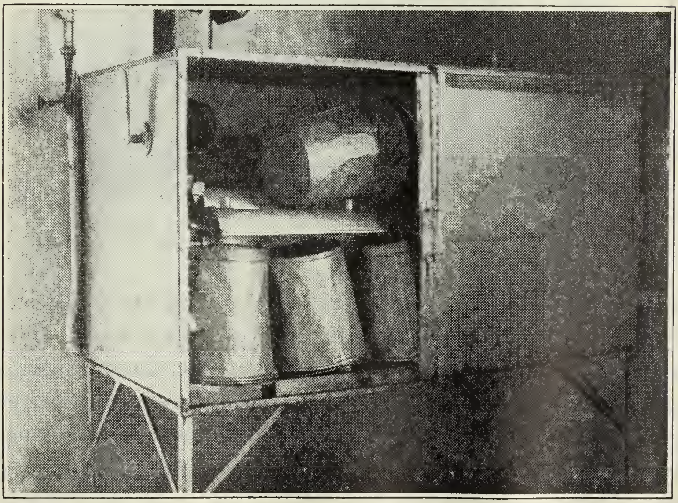

Fig. 10.—A vertical sterilizing cabinet mounted on legs and loaded with equipment.

constructed. Often an electric steam boiler has proved unsatisfactory because a leaky or oversized cabinet required an excessive amount of steam. There are two types of cabinets: the horizontal (figs. 3 and 9), constructed like a box with a lid on the top, and the vertical (figs. 4 and 10), with a door opening on the side. The horizontal type is more popular; more convenient for metal equipment, since the equipment does not

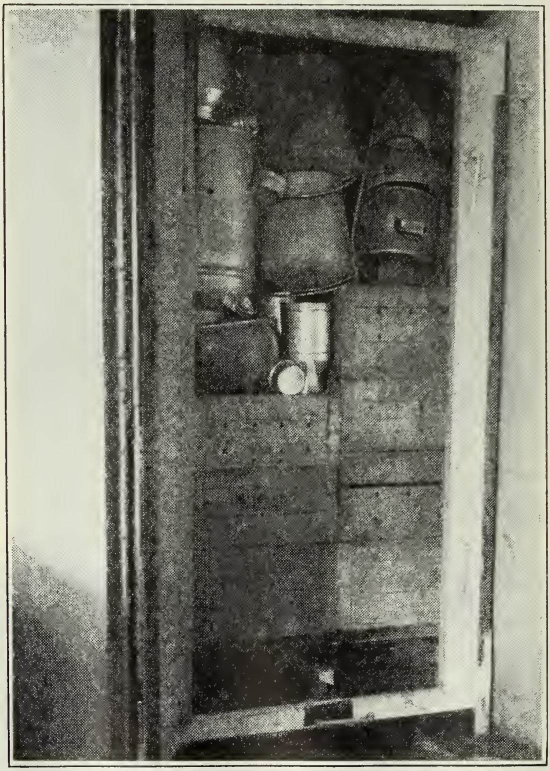

Fig. 11.—A vertical sterilizing cabinet loaded with crates of bottles and metal equipment.

have to be arranged in place; and less costly to construct because legs, door, hinges, and locks are unnecessary. The vertical type is more convenient for sterilizing bottles in crates. Although cabinets made of 20- to 24-gauge galvanized iron and uninsulated are the most common, cabinets insulated by an air space or fiberboard, or constructed of concrete or wood lined with galvanized iron are also used. The insulated and wood cabinets are lower in operating cost but higher in initial cost. Concrete cabinets usually are built as an integral part of the building, and require more steam because of the high heat capacity of the walls.

The size of the sterilizing cabinet depends on the amount and type of equipment to be sterilized. In dairies handling milk in bulk and sterilizing regular metal equipment, about 1 cubic foot of storage space is required for each 4 pounds of equipment. In dairies handling bottled milk in crates, about 15 × 20 × 12 inches for each crate of twelve quart bottles and 15 × 20 × 10 inches for each crate of twenty pint bottles will be required, besides the space needed for metal equipment (fig. 11). The

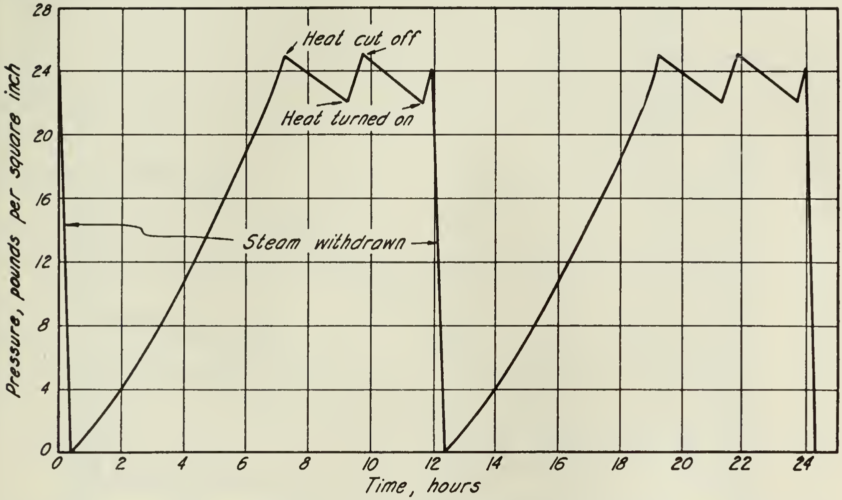

Fig. 12.—Operating cycle of an accumulator boiler set for a maximum pressure of 25 pounds per square inch.

initial cost of uninsulated galvanized iron cabinets made to order is about $1.00 per cubic foot of volume; the cost of insulated cabinets about $1.75 per cubic foot.

TESTS OF ELECTRIC STEAM BOILERS

To determine the characteristics and relative operating costs of the various boilers, laboratory tests were made on six different units—three of the accumulator type and three of the instantaneous type. These tests were made in a room where the air temperature was kept constant at 40° F.

One accumulator boiler was a 30-gallon size; the other two were the 75-gallon size. All were filled with water until the gauge glass was three fourths full. The 30-gallon boiler (*A*) had a 1,500-watt heating element and contained 24 gallons of water. One of the 75-gallon boilers (*B*) had a 1,500-watt heating element and contained 52 gallons of water, whereas the other (*C*) had a 3,000-watt heating element and contained 59 gallons. One of the instantaneous boilers (*D*) was the "no-pressure" type

(fig. 6); one (E) was a low-pressure type (fig. 8), but without the automatic water control; and one (F) was a low pressure type (fig. 7). Each of these instantaneous boilers was tested with heating elements of 5, 10, and 15 kilowatts; and they contained 5, 11, and 13 gallons of water, respectively.

Figure 12 shows a typical operating curve for an accumulator boiler set for 25 pounds' pressure and with steam withdrawn twice daily. After

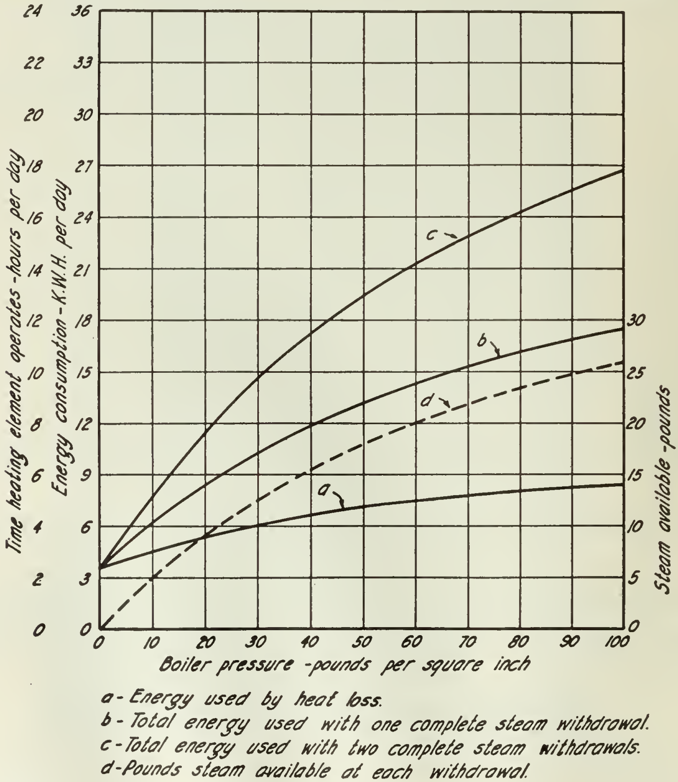

Fig. 13.—Results of tests on 30-gallon accumulator boiler A with 24 gallons of water in the boiler and a 1,500-watt heating element.

the steam has been withdrawn, the pressure gradually builds up and in about 7 hours it reaches 25 pounds, when the electricity is automatically cut off. When the pressure drops to about 22 pounds because of heat loss, the electricity is automatically turned on, and the pressure is again raised to 25 pounds. This cycle is repeated until the steam is again withdrawn.

Figures 13, 14, and 15 show the energy consumption and steam available at various pressures for the accumulator boilers tested. Curve *a*

indicates the amount of energy necessary to maintain a given pressure in an air temperature of 40° F, with no steam withdrawal. Curve *b* shows the energy used if the steam in the boiler is withdrawn once each day with a pressure drop to 0 pounds. Curve *c* indicates the energy used if the steam is withdrawn twice daily with a pressure drop to 0 for each withdrawal. Curve *d* indicates the pounds of steam available with each complete decompression of the boiler.

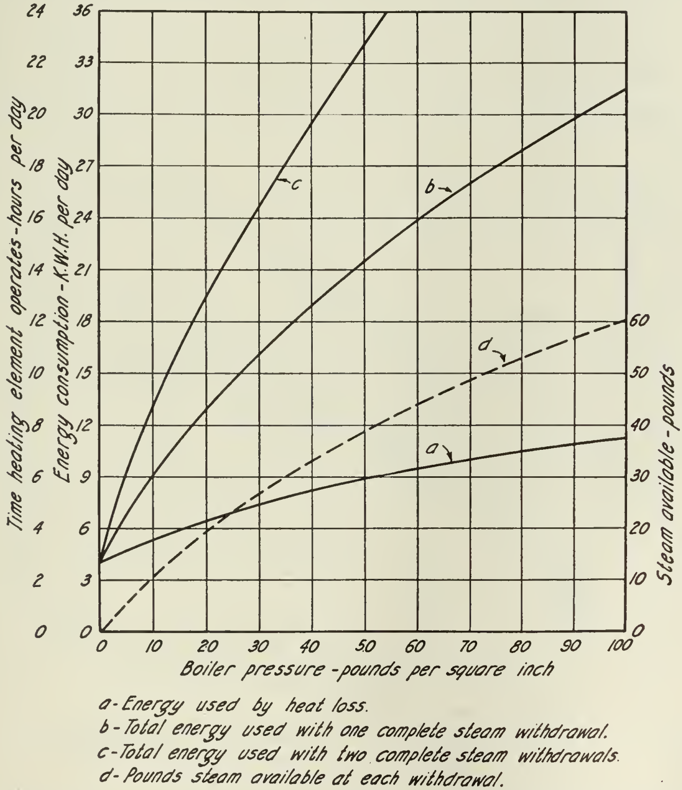

Fig. 14.—Results of tests on 75-gallon accumulator boiler *B* with 52 gallons of water in the boiler, and a 1,500-watt heating element.

Assuming a steam requirement of 25 pounds per sterilization, it would be necessary to set boiler *A* for a minimum pressure of 91 pounds, whereas boiler *B* with 52 gallons would have to be set for 28 pounds, and boiler *C* (59 gallons) for 21 pounds. With one withdrawal per day the boilers would use respectively 17, 15.5, and 15.5 kilowatt-hours daily, whereas with two withdrawals per day 26, 23.5, and 23.5 kilowatt-hours would be used. The energy consumption would be greater for the smaller boiler *A* because a higher pressure must be maintained, resulting in a

higher heat loss through the boiler shell. At the same pressure the heat loss from the small boiler *A* is less than from the two large boilers.

The heating elements in *A* and *C* were large enough to permit the operation of these boilers at 100 pounds' pressure with two complete steam withdrawals per day, whereas the element in boiler *B* was only large enough to permit the operation of this boiler at a maximum pressure of 50 pounds for two complete steam withdrawals daily.

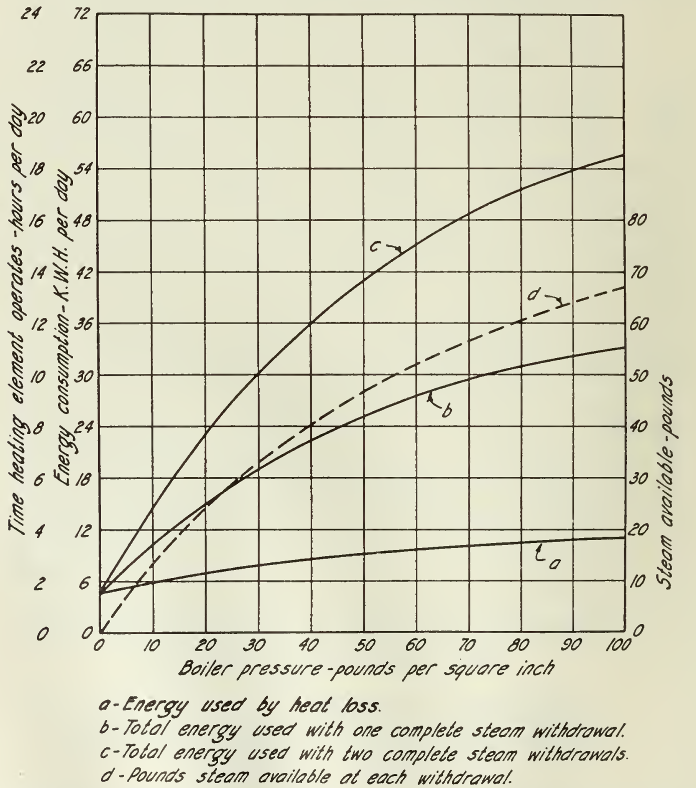

Fig. 15.—Results of tests on 75-gallon accumulator boiler *C* with 59 gallons of water in the boiler and a 3,000-watt heating element.

Table 1 shows the results of tests on the instantaneous-type boilers with connected loads of 5, 10, and 15 kilowatts. The heat loss from the uninsulated *D* was greater than for the others even though that boiler is smaller. Although both boilers were insulated, the heat loss from *E* was considerably greater than from *F* because in *E* more metal equipment was attached to the boiler shell and extended through the insulation and because the surface area was greater per unit volume due to the dome on top. The total energy required to heat the boilers to 212° F was

TABLE 1

RESULTS OF TESTS ON INSTANTANEOUS-TYPE BOILERS

Boiler	Water in boiler	Heat loss per minute at 212° F	Steam available at 15 pounds' pressure per sq. in.	Steam available at 25 pounds' pressure per sq. in.	Connected load	Time to heat from 65° to 212° F	Energy to heat from 65° to 212° F	Rate of steam generation per hour at 212° F	Energy available as steam
	gallons	*B.t.u.*	*pounds*	*pounds*	*kw.*	*minutes*	*kw.-hr.*	*pounds*	*per cent*
					5	28	2.3	13.4	81.0
D	5	52	...	...	10	13	2.2	28.7	81.5
					15	9	2.2	44.0	83.5
					5	62	5.2	14.6	83.0
E	11	48	3.7	5.3	10	30	5.0	32.2	91.5
					15	20	5.0	49.9	94.5
					5	72	6.0	15.7	89.5
F	13	30	4.4	6.2	10	35	5.8	33.3	94.5
					15	23	5.8	50.5	96.5

TABLE 2

COMPARISON OF THE ENERGY CONSUMPTION OF ALL THE BOILERS, WITH TWO DIFFERENT STEAM REQUIREMENTS

Boiler*	Water in boiler, gallons	Initial steam pressure, pounds per sq. in.	Energy available as steam, kw.-hr. per day†	Energy lost, kw.-hr. per day	Total energy used, kw.-hr. per day
One sterilization per day using 40 pounds of steam					
B	52	53	13.1	9.0	22.1
C	59	40	13.1	8.5	21.6
D	5	0	13.1	3.9	17.0
E	11	0	13.1	4.9	18.0
F	13	0	13.1	4.7	17.8
Two sterilizations using 20 pounds of steam each sterilization					
A‡	24	60	13.1	7.5	20.6
B	52	21	13.1	6.5	19.6
C	59	16	13.1	6.5	19.6
D	5	0	13.1	6.1	19.2
E	11	0	13.1	8.2	21 3
F	13	0	13.1	6.9	20.0

* Boilers *D*, *E*, and *F* were of the instantaneous type, with connected load of 10 kilowatts.

† Includes energy to heat water from 65° to 212° F.

‡ Will not supply 40 pounds of steam with one withdrawal.

slightly greater with a 5-kilowatt connected load because the longer heating time contributed to a greater heat loss. With 10- and 15-kilowatt connected loads the energy requirements were practically the same. The rate of steam generation and percentage of the energy available as steam was least in boiler *D* because of the higher heat loss and also because the

water drawn off as steam was replaced immediately by tap water at 65°, which had to be heated to 212°. In boilers *E* and *F* all the heat except that lost through the boiler shells was used in generating steam.

Table 2 analyzes the operation of all the boilers when supplying 40 pounds of steam once daily and 20 pounds of steam twice daily. The data for the instantaneous boilers (*D, E,* and *F*) are based on a connected load of 10 kilowatts and operation at zero pressure. If operated at initial

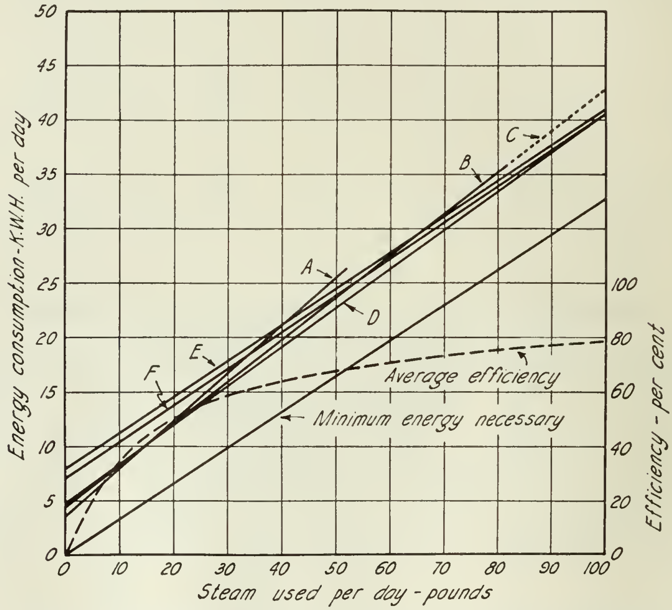

Fig. 16.—Comparison of the energy consumption of all the boilers tested when supplying various quantities of steam with two withdrawals daily.

pressures of 15 to 25 pounds, these boilers would have an energy consumption of 0.5 to 1 kilowatt-hours more per day. The minimum energy necessary to supply 40 pounds of steam per day is 13.1 kilowatt-hours, which includes the latent heat of vaporization and the heat necessary to raise the water from 65° to 212° F. The difference between 13.1 and the actual kilowatt-hours used is the energy lost, whereas the ratio between them is the thermal efficiency of the boiler. Since the accumulator boilers operate continuously, their heat loss depends upon the effectiveness of the insulation and upon the pressures maintained. Instantaneous boilers, however, operate only a few hours daily; their heat loss depends not only on the insulation but also on the amount of heat left in the boiler when it is turned off. If, for example, boiler *F*, which starts with 13 gallons of water, converts 5 gallons into steam and is left with 8 gallons at 212°

when it is turned off, the heat loss between sterilizing periods is greater than when 9 gallons are converted into steam and only 4 gallons remain. This heat loss must be made up each time the boiler is used; consequently, a boiler used twice daily has a higher energy consumption than one used only once daily. This reduction in heat loss when the boiler is used only once a day explains why the total energy consumption for the instantaneous boilers is less than for the accumulators when the boilers are supplying 40 pounds of steam once daily and is practically the same when they are supplying 40 pounds with two sterilizations daily.

Figure 16 compares the energy consumption of all the boilers when supplying various quantities of steam with two sterilizing periods per

TABLE 3

EFFECT OF THE RATE OF HEATING UPON THE QUANTITY OF STEAM REQUIRED TO HEAT UNINSULATED STERILIZING CABINETS IN AN AIR TEMPERATURE OF 40° F

Rate of heating, pounds steam per minute	Size of heating element in boiler, kilowatts	Time to heat to 170° F, minutes		Amount of steam to heat to 170° F, pounds		Amount of steam to maintain above 170° F for 15 minutes,* pounds		Total amount of steam necessary, pounds	
		Empty	Loaded	Empty	Loaded	Empty	Loaded	Empty	Loaded
Cabinet volume, 22½ cubic feet; load 125 pounds of metal									
0.24	5	22.5	41.7	5.5	10.2	2.4	2.4	7.9	12.6
0.54	10	6.2	9.5	3.3	5.1	5.4	5.4	8.7	10.5
0.83	15	4.0	6.1	3.3	5.1	8.3	8.3	11.6	13.4
Cabinet volume, 37½ cubic feet; load 230 pounds									
0.24	5	47.8	....	11.7	....	2.4	...	14.1	....
0.54	10	9.7	21.5	5.2	10.5	5.4	5.4	10.6	15.9
0.83	15	5.4	11.8	4.4	9.8	8.3	8.3	12.7	18.1

* Based on steam input for 10 minutes after reaching 170° F.

day. The energy consumption for the instantaneous boilers does not increase so rapidly with the quantity of steam used as for the accumulators. The reason is that the thermal efficiency increases more rapidly when more of the water is turned into steam and less heat is left in the boilers. With all the boilers the thermal efficiency increases as more steam is used.

STEAM REQUIREMENTS OF STERILIZING CABINETS

To determine the importance of various factors on the steam required to heat sterilizing cabinets, laboratory observations were made on the steam requirements as influenced by rate of heating, size of cabinet, insulation, air temperature surrounding the cabinet, and load.

The cabinet used for these observations was a specially made horizontal type, 3 feet wide by 2½ high, and so constructed that the length could be varied from 3 to 6 feet. An outer shell could be placed around it to provide insulation of ½-inch dead air space or ½-inch thickness of fiberboard. The inner shell was of 20-gauge and the outer shell of 26-gauge galvanized iron. The observations (except those on the effect of air temperature) were made in a room where the air temperature was kept constant at 40° F. The temperatures in the cabinet were taken both

TABLE 4

EFFECT OF SIZE OF CHAMBER UPON THE QUANTITY OF STEAM REQUIRED TO HEAT UNINSULATED EMPTY STERILIZING CABINETS IN AN AIR TEMPERATURE OF 40° F

Size of chamber	Size of heating element in boiler	Time to heat to 170° F	Time to heat to 200° F	Amount of steam to heat to 170° F	Amount of steam to heat to 200° F
cubic feet	*kilowatts*	*minutes*	*minutes*	*pounds*	*pounds*
22.5	5	22.5	150.5	5.5	36.7
	10	6.2	10.7	3.3	5.4
	15	4.0	6.4	3.3	5.4
30.0	5	32.5	....*	7.9	...
	10	7.1	13.8	3.8	7.4
	15	4.9	8.6	4.1	7.1
37.5	5	47.8	....	11.7	...
	10	9.7	18.9	5.2	9.9
	15	5.4	9.7	4.4	8.1
45.0	5	....	....	...	...
	10	11.3	23.8	6.1	12.8
	15	6.1	11.2	5.1	9.3

* Could not be heated to indicated temperatures.

at the bottom and top near the end opposite from that where the steam was admitted.

Effect of Rate of Heating.—Table 3 shows the effect upon the time and quantity of steam necessary to heat a cabinet with various rates of heating. In comparing the results obtained with a rate of heating as supplied by 5 kilowatts with the results for 10 and 15 kilowatts, one sees that there is a minimum rate practicable for a cabinet of given size. If the rate is too slow, the time required to heat becomes excessive, resulting in a waste of steam; or it may be impossible to raise the temperature to 170° F because at that point the heat loss is greater than the heat input. The results with rates supplied by 10 and 15 kilowatts show that with the faster rate of heating less time and, for the larger cabinet, less steam are required to heat to 170°. To hold the temperature above 170° for 15 minutes, however, less steam is wasted with the lower rate of heating.

Effect of Size of Cabinet.—Table 4 shows how the cabinet size affects the time and quantity of steam required for heating. As the results indicate, both the time and the amount of steam increase with the size of cabinet, but not in direct proportion. They also show that there is a limit to the size of cabinet that can be heated to the required temperature by a given rate of heating, about 20 cubic feet being the maximum with a 5-kilowatt heating element and about 45 cubic feet with a 10-kilowatt heating element.

Effect of Insulation.—Table 5 shows how insulation affects the time and amount of steam necessary for heating. With a sufficient rate of heating, little is gained from insulation in the time and amount of steam necessary to heat to 170° F; but to hold the temperature above 170° requires less steam in the insulated cabinet. When the rate of heating is relatively slow, both time and steam are saved by insulated cabinets. There was little difference in the steam required to heat the cabinets insulated by an air space and by fiberboard, and in general both kinds required about one third less steam than the uninsulated cabinets.

TABLE 5

Effect of Insulation Upon the Steam Required to Heat Empty Sterilizing Cabinets of 30-Cubic Foot Capacity in an Air Temperature of 40° F

Insulation	Time to heat to 170° F, minutes	Steam to heat to 170° F, pounds	Steam to maintain above 170° F for 15 minutes, pounds	Time to cool from 200° F to 170° F, minutes
10-kilowatt heating element				
Uninsulated	7.1	3.8	5.2	5.3
½-inch air space	6.4	3.4	2.7	10.3
½-inch fiberboard	7.2	3.9	2.7	10.8
5-kilowatt heating element				
Uninsulated	32.5	7.9	3.0	....
½-inch air space	19.6	4.8	2.2	12.0
½-inch fiberboard	21.9	5.3	2.0	14.6

Effect of Air Temperature.—Table 6 shows how the air temperature surrounding a cabinet affects the total time and amount of steam necessary for heating to a given temperature. As a comparison of the data shows, the time and the amount of steam needed decrease as the outside temperature increases. Since sterilizing is necessary in both winter and summer, a cabinet must be designed to meet the most extreme conditions.

Effect of Load in Cabinet.—Table 3 shows how the load in the cabinet

affects the total time and the amount of steam necessary for heating. When the rate of heating is rapid, as was possible with 10 and 15 kilowatts and the 22½-cubic foot cabinet, the time and quantity of steam are increased by approximately the amount necessary to heat the load. When the rate of heating is slow, as with 5 kilowatts and the 22½-cubic foot cabinet, the time and amount of steam are increased by more than that necessary to heat the load. The amount of steam necessary to heat metal equipment is approximately the weight times the number of degrees the temperature is raised divided by 10,000. For example, the steam necessary to heat 100 pounds of equipment from 40° F to 170° would be

TABLE 6

EFFECT OF AIR TEMPERATURE UPON THE ENERGY REQUIRED TO HEAT A STERILIZING CABINET WITH 10- AND 15-KILOWATT HEATING ELEMENTS

Air temperature	Time to heat to 170° F		Time to heat to 200° F		Steam to heat to 170° F		Steam to heat to 200° F	
	10 kw.	15 kw.	10 kw.	15 kw.	10 kw.	15 kw.	10 kw.	15 kw.
degrees F	*minutes*	*minutes*	*minutes*	*minutes*	*pounds*	*pounds*	*pounds*	*pounds*
40	21.5	11.8	34.7	17.0	11.5	9.8	18.6	14.1
50	18.0	10.8	30.0	15.7	9.7	9.0	16.1	13.1
60	16.0	9.9	27.0	14.6	8.6	8.2	14.5	12.1
80	13.5	8.8	22.3	12.8	7.3	7.3	12.0	10.6

$$\frac{100 \times (170 - 40)}{10{,}000} = \frac{100 \times 130}{10{,}000}$$

or 1.3 pounds. The heat required by glass is approximately double that for metal.

STEAM REQUIREMENTS FOR HEATING WATER

To determine the amount of steam required to heat water in sinks, laboratory experiments were conducted with a vat resembling in size and shape the sinks commonly used on dairies. The vat was made from a 50-gallon metal oil drum cut in half so that its cross section was semicircular. The tests were conducted in a room where the air temperature was maintained constant at 40° F; and steam, supplied by an instantaneous-type boiler, was exhausted into the vat water through a perforated pipe on the bottom.

Table 7 shows the amount of steam required to heat from 5 to 25 gallons of water to various temperatures when using a boiler with a 15-kilowatt heating element. Table 8 compares the time and amount of steam required to heat 10 gallons of water at various rates of heating. The rate of heating as supplied by the 10-kilowatt heating element required the

least amount of steam to heat water to 125° F or above. With 5 kilowatts the heat loss was excessive because of the longer heating time, whereas with 15 kilowatts considerable steam escaped from the water. In general from one fourth to one third more steam was required to heat the water than the theoretical amount necessary if no heat losses occurred.

TABLE 7

Amount of Steam Necessary to Heat Water in an Open Steel 25-Gallon Semicircular Vat in a Room Temperatue of 40° F, at a Heating Rate of 0.83 Pound Steam per Minute

Quantity of water, gallons	Pounds steam required to heat water to the given temperatures					
	60°	100°	125°	150°	175°	200°
5	0	2.4	3.3	4.5	5.8	7.5
10	0	4.2	6.2	9.0	11.9	15.6
15	0	5.5	8.6	12.1	16.0	21.8
20	0	6.9	11.0	15.9	21.4	29.3
25	0	8.6	13.6	19.8	26.8	37.2

TABLE 8

Comparison of Time and Amount of Steam Necessary to Heat 10 Gallons of Water in an Open Vat at Various Rates of Heating in a Room Temperature of 40° F, and with an Initial Water Temperature of 60°

Size of heating element in boiler, kw.	Rate of heating, pounds steam per minute	Time and weight of steam required to heat water to the given temperatures									
		100°		125°		150°		175°		200°	
		minutes	*pounds*	*minutes*	*pounds*	*minutes*	*pounds*	*minutes*	*pounds*	*minutes*	*pounds*
5	0.24	14.3	3.5	26.0	6.3	40.5	9.9	68.0	16.6	....	....
10	0.54	7.2	3.9	10.8	5.8	15.1	8.1	20.4	11.2	28.5	15.4
15	0.83	5.1	4.2	7.5	6.2	10.8	9.0	14.3	11.9	18.5	15.6
Amount necessary if no losses occur		....	3.3	....	5.4	....	7.5	....	9.5	....	11.6

SURVEY OF STERILIZING OPERATIONS ON DAIRY FARMS

Sterilizing equipment and operations were surveyed on eighteen dairy farms of 20 to 210 cows each, located in the Sacramento Valley and Marin County. Fifteen of the dairies were selling market milk in bulk, and three were selling bottled milk. This survey was conducted in the spring, when the air temperature was usually between 50° and 60° F during the observation periods. The results appear in table 9.

The equipment sterilized on the dairies handling milk in bulk consisted mainly of the milking machines and various other milk-handling equip-

TABLE 9

RESULTS OF SURVEY OF STERILIZING OPERATIONS AS PRACTICED BY TYPICAL CALIFORNIA DAIRIES*

Dairy no.	Number of cows in dairy	Type of sterilizer	Connected load, kw.	Size of sterilizing cabinet, cu. ft.	Amount of equipment sterilized, pounds	Amount of heated water used, gallons	Temperature of heated water, degrees F	Pounds of steam used in the various operations: Water heating	Heating sterilizing cabinet	Sterilizing aerator	Total
Dairies handling milk in bulk											
1	29	Accumulator boiler	1.5	17	32	9	126	5.0	5.2	0.0	10.2
2	35	Self-contained	5.0	15	50	3	120	(3)†	5.5	0.0	8.5
3	36	Accumulator boiler	1.5	27	103	....‡	....	0.0	13.0	0.0	13.0
4	38	Accumulator boiler	1.5	22	100	16	116	6.5	11.0	5.0	22.5
5	38	Instantaneous boiler	10.0	39	45	10	120	(8)†	25.0	2.7	35.7
6	44	Accumulator boiler	1.5	30	61	9	115	5.0	10.0	0.0	15.0
7	50	Instantaneous boiler	15.0	14	62	16	130	(11)†	9.5	0.0	21.5
8	55	Accumulator boiler	1.5	21	56	20	115	8.0	4.0	3.0	15.0
9	55	Accumulator boiler	3.0	28	120	17 8§	108 165	7.0 12.0	9.0	1.0	17.0
10	60	Accumulator boiler	1.5	29	61	5	....	2.5	14.0	3.0	19.5
11	78	Instantaneous boiler	15.0	14	44	12	132	(9)†	10.0	0.0	19.0
12	86	Instantaneous boiler	15.0	38	140	18 23§	125 180	10.0 45.0	9.0	0.0	19.0
13	90	Accumulator boiler	1.5	17	89	13	118	6.0	11.5	2.0	19.5
14	120	Instantaneous boiler	15.0	38	113	23 8§	96 140	8.0 7.0	15.0	4.0	27.0
15	210	Instantaneous boiler	15.0	27	105	36	165	48.0	47.5	4.3	122.3
		Accumulator boiler	3.0	23	92	....	....	....	16.5	6.0	....
Dairies handling bottled milk											
16	20	Accumulator boiler	1.5	26	261	15	....	6.0	15.0	2.0	23.0
17	38	Instantaneous boiler	10.0	91	1,081	16	120	25.0	43.0	2.0	70.0
18	63	Instantaneous boiler	15.0	24	221	18	130	17.0	20.0	3.0	40.0

* Quantities are for each sterilization.
† Obtain hot water directly from boiler; figure represents equivalent pounds of steam to heat the water.
‡ Heats water by wood stove.
§ Sterilize rubber equipment of milking machines in hot water once a day.

ment such as pails, surface-cooler troughs, vats, and the surface cooler. There was little correlation between the size of the dairy and the amount of equipment, the range being 0.6 to 2.9 pounds per cow and the average 1.4 pounds. On the dairies handling bottled milk, crates and bottles were sterilized along with the regular milk-handling equipment.

The common sterilizing practice was to wash the equipment in warm water and then, with the exception of the surface cooler, place it in the cabinet for sterilizing. The surface cooler was sterilized in place by steam or by hot water. Sometimes the rubber parts of the milking machines were sterilized separately from the other equipment by being placed in hot water. In most of the dairies the amount of water required for washing purposes was between 10 and 20 gallons, and this was heated to a temperature between 110° and 130° F. A majority heated the water by steam, but a few obtained hot water directly from the boiler.

The sterilizing cabinets were both the horizontal and the vertical types; and except for one cabinet made of concrete and another insulated with fiberboard, all were of galvanized iron uninsulated. Many were in such condition that steam leaked from them freely, and over half were larger than necessary. On some dairies the boilers did not have sufficient capacity to heat the cabinets to 170° F. Only a few cabinets were equipped with thermometers; the temperature and the time usually being a matter of guesswork. The equipment was normally placed in the cabinet in an inverted position so that water would drain off; and as soon as the sterilizing was completed, the lid or the door of the cabinet was opened to permit the equipment to dry.

The amount of steam used for water heating varied from 3 to 48 pounds, the majority using between 5 and 10. The steam used for heating the sterilizing cabinets varied from 4 to 48 pounds, the usual amount being 9 to 15. The steam used for sterilizing surface coolers varied from 1 to 5 pounds, the average being about 3. The total steam used per sterilization varied from 0.22 to 0.94 pound per cow, with an average of 0.38.

The principal trouble experienced with the sterilizers was burning out of the heating elements, especially where hard-water conditions obtained and instantaneous boilers were used. Some dairymen overcame this difficulty by installing water softeners in conjunction with the boilers, but it was always necessary to clean the scale from the heating elements periodically, the frequency depending upon the water hardness. Other troubles reported were leaky connections and the failure of regulating or protective equipment.

Sometimes waste resulted from allowing more steam to escape from the exhaust valve than could be used economically. One dairyman, using an accumulator boiler starting with 40 pounds' pressure, opened the

valve to the sterilizing cabinet to the maximum and reduced the pressure in the boiler to 4 pounds, yet held the temperature in the cabinet above 170° F for only 6 minutes. By throttling down the valve after the temperature in the cabinet reached 170°, he could hold the temperature above that point for the required 15 minutes and still have 9 pounds' pressure left in the boiler. Some instantaneous boilers have been installed with a switching arrangement whereby 5, 10, or 15 kilowatts could be

TABLE 10

AVERAGE ENERGY CONSUMPTION AND OPERATING COSTS OF ELECTRIC STERILIZERS IN OPERATION ON DAIRY FARMS

Number of dairies in group	Number of cows per dairy	Energy consumption per month per dairy, kw.-hr.	Energy consumption per month per cow, kw.-hr.	Cost of energy per month per dairy, dollars	Cost of energy per month per cow, dollars
Dairies selling bulk milk					
4	15– 30	272	11.6	3.82	0.16
5	30– 45	475	11.9	5.66	.14
7	45– 60	553	10.5	6.69	.13
8	60– 75	623	9.4	6.92	.10
6	75–100	777	9.4	9.33	.12
6	100–140	958	7.9	9.64	.08
4	140–250	1,468	8.5	12.89	0.08
Retail dairies					
1	9	450	50.0	5.40	0.60
1	14	450	32.1	4.50	.32
1	38	750	19.7	9.00	.24
1	46	850	18.5	10.20	.22
1	63	900	14.3	10.80	.17
1	100	2,200	22.0	18.70	0.19

turned on as needed. Often the lid on the sterilizing cabinet was removed as soon as the steam was turned off regardless of the time held above 170°, whereas if the lid had been left on until the temperature had dropped to 170° the time requirement would have been met without additional steam consumption.

OPERATING COSTS OF ELECTRIC STERILIZERS

To determine the operating costs of sterilizers in actual use, watt-hour meters were connected to the sterilizers on several farm installations. These meters were read once each month for one year, with the results shown in table 10.

The sterilizers on the forty dairies (of 15 to 250 cows each) handling milk in bulk used 4.2 to 20.0 kilowatt-hours per cow per month, with an

average of 10.2 kilowatt-hours. The cost of the energy ranged from 4 to 35 cents per cow per month, the average being 13 cents. The sterilizers on the retail dairies (9 to 100) cows used 14.3 to 50.0 kilowatt-hours per cow per month at a cost of 17 to 60 cents. On the four retail dairies with more than 30 cows, the energy consumption averaged about 18 kilowatt-hours per cow per month—an average of 20 cents per cow per month.

The unit cost of the electric energy varied from 0.8 to 3.0 cents per kilowatt-hour according to the power company serving the dairy, the rate (agricultural or domestic) under which the charge was made, and the amount of energy used both by the sterilizer and by all other electric equipment. The average rate was 1¼ cents per kilowatt-hour.

CONCLUSIONS AND RECOMMENDATIONS

Electrically operated dairy-equipment sterilizers have proved practical and, having certain advantages over other types, are commonly used.

Two types of electric sterilizers, the "self-contained" with the steam generator and sterilizing cabinet as one unit, and the "boiler" with the steam generator and sterilizing cabinet as separate units, are being manufactured and sold in California.

The self-contained sterilizer is the most economical in both initial and operating costs, but does not supply controlled steam.

In purchasing the self-contained sterilizer, the dairyman is advised to obtain the heating element with the automatic device for turning it off when not immersed. To prevent the burning out of one element will more than offset the additional cost.

As the energy consumption of the various steam boilers available is approximately the same, the choice among types must depend upon the individual features.

The accumulator boilers are less troublesome where hard water is used. A water softener should be installed in conjunction with the instantaneous boilers for hard-water conditions.

With all types of sterilizers the heating elements should be inspected for scale, and the boiler cleaned out periodically.

The safety valves on boilers should be checked at least once each week to see whether they are working properly.

A shut-off valve should not be placed in the exhaust line of the no-pressure-type instantaneous boiler. A two-way valve may be used to turn the steam into the sterilizing cabinet or into a hose line.

The boiler should be located as near the sterilizing cabinet as practicable in order to reduce the length of steam pipe necessary for connecting the two. A ½- or ¾-inch pipe is large enough for the steam line. Large and long pipes increase heat loss.

Horizontal sterilizing cabinets are more convenient for metal equipment, whereas vertical cabinets are more convenient for bottles in crates.

Sterilizing cabinets should be reasonably free from leaks and only large enough to accommodate the equipment to be sterilized.

Insulating an iron cabinet with a ½-inch air space or with ½-inch fiberboard will decrease the amount of steam needed for sterilization by about one third. An insulated cabinet when heated to 200° F will remain above 170° for 10 to 12 minutes without additional heat, whereas the uninsulated type will cool to 170° in about 5 minutes.

In heating a cabinet by a boiler with stored steam, the temperature should be raised to 170° F as quickly as possible, and then the steam flow cut down to maintain the temperature a few degrees above that point for the required time. Large volumes of steam escaping from the cabinet indicate excessive flow.

The attention given by the operator and the methods of operation materially affect efficiency and the operating costs of the equipment.

The following are approximate figures for estimating sizes and quantities on average dairies of 25 to 150 cows. In general the larger dairies approach the minimum figure, the smaller dairies the maximum.

a. Weight of metal milk-handling equipment per cow, 1 to 2 pounds.

b. Volume of sterilizer cabinet per cow for metal equipment, ⅓ to ½ cubic foot.

c. Volume of sterilizer cabinet for a 12-quart-bottle crate, 15 × 20 × 11 inches; for a 20-pint-bottle crate, 15 × 20 × 9 inches.

d. Quantity of steam to sterilize in an uninsulated iron cabinet filled with metal equipment, ⅓ to ½ pound per cubic foot.

e. Quantity of steam to sterilize in an uninsulated iron cabinet filled with crates of bottles, ½ to ¾ pound per cubic foot.

f. Quantity of steam to heat 5 gallons of water from 60° to 125° F in an open metal container, 3 pounds.

g. Quantity of steam for each washing and sterilizing on bulk milk dairies, ⅓ to ½ pound per cow.

h. Maximum volume of cabinet for sterilizing by instantaneous heat from a boiler, 20 cubic feet per 5 kilowatts of heating capacity.

i. Energy consumption of sterilizers, 8 to 12 kilowatt-hours per cow per month for bulk-milk dairies; 15–20 kilowatt-hours per cow per month for retail dairies.

j. Operating cost of electric sterilizer, 10 to 15 cents per cow per month for bulk-milk dairies, 15 to 25 cents per cow per month for retail dairies.

ACKNOWLEDGMENTS

The authors wish to express their appreciation and thanks to the various dairy farmers and electric companies who aided in obtaining data, and to the following manufacturers who loaned equipment for testing: Wellman Bros., Modesto; Thermador Electric Manufacturing Co., Los Angeles; Wesix Electric Co., San Francisco; and North Bay Electric Works, San Rafael.

15m-6,'41(2834)